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ROLIC AG [/]; (). SCHMITT, Klaus [/]; (). SEIBERLE, Hubert [/]; (). SCHADT, Martin [/]; (). SCHMITT, Klaus [/]; (). SEIBERLE, Hubert [/]; (). SCHADT, Martin [/]; (). NEVILLE, Peter, Warwick ; ().

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(54) **Title: LIQUID CRYSTAL DISPLAY WITH IMPROVED VIEWING ANGLE**
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(57) Abstract

To improve the viewing angle of a liquid crystal display, it is provided with a compensating layer consisting of a cross-linked cholesteric liquid polymer layer with a very short helix pitch and the helix axis normal to the layer. The layer has negative uniaxial optical anisotropy.

(57) Abrégé

Afin d'améliorer l'angle d'observation d'un affichage à cristaux liquides, on prévoit une couche de compensation consistant en un couche de polymère liquide cholestérique réticulé possédant un pas d'hélice très petit, l'axe de l'hélice étant parallèle à la couche. Ladite couche possède une anisotropie optique monoaxiale négative.

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(54) Title: LIQUID CRYSTAL DISPLAY WITH IMPROVED VIEWING ANGLE

(57) Abstract

To improve the viewing angle of a liquid crystal display, it is provided with a compensating layer consisting of a cross–linked cholesteric liquid polymer layer with a very short helix pitch and the helix axis normal to the layer. The layer has negative uniaxial optical anisotropy.

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Description

LIQUID CRYSTAL DISPLAY WITH IMPROVED VIEWING ANGLE

This invention relates to a liquid crystal display, and in particular to a compensator for improving the viewing angle of the display.

Liquid crystal displays (LCDs) usually show a distinctive viewing angle dependency of the contrast. Particularly affected are configurations where the dark state is realised by the liquid crystal director being perpendicular to the cell plane. This is the case for instance with vertically aligned nematic (VAN) cells, hybrid aligned nematic (HAN) cells, and normally white twisted nematic (TN) cells. The contrast of these cell types is very high in case of perpendicular incidence of light, and is reduced with increasing viewing angle (considering a perpendicular view to represent "viewing angle" of zero). For large viewing angles the contrast can even be inverted. Switched states of the LCD where the liquid crystal director is tilted with respect of the cell normal have an asymmetrical viewing angle dependency.

The undesirable viewing angle dependency can be reduced by disposing in the cell a compensator with a layer having a negative uniaxial optical anisotropy. In the case of the VAN cell, the optical anisotropy of the non-driven state is such that the refractive index n_x, n_y in the cell plane is smaller than the refractive index n_z in the direction perpendicular to the plane, i.e. $n_z > n_x = n_y$, and can thus be compensated by a second birefringent layer but with negative optical anisotropy, i.e. with $n_z < n_x = n_y$. In the same way, the driven state of a HAN cell or of a normally white TN cell can be compensated.

The invention is about such a compensator.

According to the present invention, there is provided a compensator comprising a layer of a cholesteric liquid crystal polymer (LCP) having a helix axis normal, or generally or essentially or substantially normal, to the plane of the layer and having a

helix pitch sufficiently short that the selective reflection range is of shorter wavelength than visible light. A suitable pitch would therefore be less than 300nm, preferably less than 200nm, such as less than 150nm.

Alternatively reckoned, a suitable pitch can be less than $350nm/\bar{n}$ where $\bar{n}$ is the mean refractive index of the polymer.

Preferably, the cholesteric liquid crystal is applied and polymerised in situ, for example cross-linked.

Advantageously, the optical anisotropy Δn of the liquid crystal polymer exceeds 0.25, as a high optical anisotropy enables thinner compensating layers.

Preferably, the layer has a cholesteric arrangement over at least part of its area.

The polymer layer may be photo-oriented, conveniently adopting the orientation of an underlying linearly photopolymerised layer.

The invention extends to a liquid crystal display (LCD) device comprising a compensator as set forth above, which compensator preferably extends to the whole viewing area of the device.

The LCD device may, in either its white or dark state, have the director of its switching liquid crystal material aligned essentially normal to the compensator.

The liquid crystal cell of the LCD device may be vertically aligned nematic, hybrid aligned nematic or twisted nematic (VAN, HAN or TN), being liquid crystal classes already indicated as affected by a viewing angle dependency capable of some compensation.

A typical compensator according to the invention may thus consist of a cross-linked cholesteric liquid crystal polymer layer having a helix axis that is parallel to the cell normal (perpendicular to the cell plane) and having a helix pitch that is so small that the visible light ($\lambda > 400$ nm) lies on the long-wavelength side of the selective reflection range ($\lambda_0 < 350$ nm) where λ_0 is the centre wavelength of the selective reflection band. With these conditions of the cholesteric arrangement, light passing through vertically experiences the mean refractive index $\bar{n} = (n_o + n_e)/2$ of the cholesteric layer. The optical axis is normal to the layer and has the refractive index n_o, whereas the effective refractive index in the plane is $(n_o + n_e)/2 > n_o$ and therefore, the cholesteric layer is a negative uniaxial layer for visible light.
n_e and n_o are the respective local extraordinary and ordinary refractive indices of the cholesteric layer.

By choosing a suitable thickness for the compensating layer in relation to the liquid crystal device in which it is to be incorporated, the anisotropy of the positive uniaxial liquid crystal cell will be compensated.

For the manufacturing of the LCPs used, preferably monomers or prepolymers in solution are applied on an orientation layer. The viscosity is preferably arranged to be so low that the orientation takes place within a short period of time. The cholesteric arrangement can be induced by a chiral dopant having a high helical twisting power (HTP), whereby pitches of less than 250 nm may be reached easily. An ensuing curing or cross-linking of the layer can make it mechanically robust and its optical properties thermally stable. To compensate a typical VAN cell, where the optical retardation $\Delta n^*d = 250..500$ nm (optical anisotropy Δn, cell thickness d), due to the large anisotropy of the LCP material, a layer thickness of a few micrometers is sufficient.

To orient the cholesteric LCP, in principle any of the known orientation layer techniques may be used. Particularly suitable are photo-orientation methods (usually using linearly polarised light), and especially good orientation properties can be achieved by linearly photo-polymerised (LPP) orientation layers. These methods advantageously also avoid possible optical defects, such as grooves or scratches caused by rubbing.

By using a cholesteric LCP in this way, i.e. a cured or cross-linked cholesteric liquid crystal composition based on monomers or pre-polymers, a fast orientation of high quality may be achieved, useful for large-scale manufacturing.

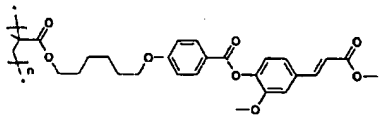
Compensating layers according to the invention can be easily incorporated into liquid crystal polymer multi-layers.

The invention will now be described by way of example and with reference to the accompanying drawings, which show the viewing angle characteristics of cells with and without compensating layers according to the invention, as described later.

An example of a compensating layer according to the invention is made as follows.

In a first step, a linearly photopolymerisable (LPP) orientation layer was applied to a quartz substrate. For this, a 1 wt% solution S_{LPP} of the photoaligning polymerisable photopolymer material A was prepared using cyclopentanone as a solvent.

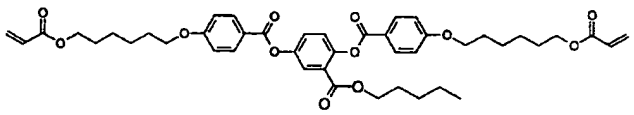
Photopolymer A:



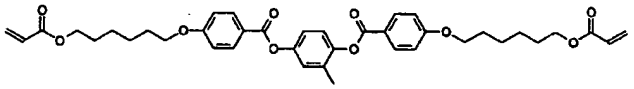
The solution S_{LPP} was spincoated on the substrate at 2000 rpm for 2 minutes at 23°C. The about 50 nm thick layer was subsequently annealed at 150°C for 30 minutes in air. Then the coated substrate was exposed for ten minutes to the linearly polarised light of a mercury lamp, to impart photoalignment and to polymerise it.

In a second step, a cholesteric LCP layer was spincoated onto the orientation layer. For this, a solution S_{LCP} was prepared, which contained three liquid cristalline diacrylate monomers Mon1, Mon2, Mon3,

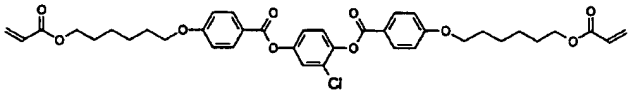
Mon1:



Mon2:

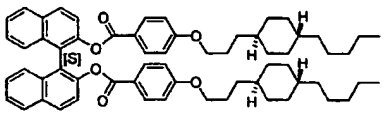


Mon3:



a chiral component Ch1,

Ch1:



and in addition photoinitiator IRGACURE 369 from Ciba SC as well as BHT (2,6-di-tert-butyl-4-methylphenol/"butyl hydroxytoluene") that served as an inhibitor, all dissolved in anisole.

Thus the composition of the solution S_{LCP} was as follows:

Mon1	24 wt%
Mon2	4.5 wt%
Mon3	1.5 wt%
Ch1	3 wt%
Irgacure 369	0.5 wt%
BHT	0.5 wt%
Anisole	66 wt%

The layer was tempered at 23 °C for some minutes, and then – after a cholesteric mono-domain layer had been formed – crosslinked under nitrogen atmosphere by exposing it to unpolarised mercury light for five minutes. Subsequently, the LPP/LCP layer was tempered at 200 °C for six minutes in air.

The transmission spectrum of the coated quartz plate showed a selective reflection band of the cholesteric layer at the centre wavelength $\lambda_0 = 350$ nm. The thickness of the layer was 3.2 µm.

A second LCP layer was then spincoated, oriented and crosslinked in the same manner as described above, leading to a total thickness of the multi-layer of 6.5 µm. The centre wavelength of the selective reflection of the LCP double layer remained 350 nm.

Angle dependent reflection measurements in an ellipsometer ("WVASE" of J.A. Woollam Co.) showed that the LCP double layer has in the range of the visible light (400..800 nm) the characteristics of a negative uniaxial double refractive layer with its optical axis parallel to the layer normal and with an optical anisotropy

$$\Delta n = n_o - (n_o + n_e)/2 = -0.07 .$$

In a further experiment, this compensating layer was cemented to a VAN cell, the optical anisotropy of which was $\Delta n^*d = 420$ nm. Viewing angle dependency measurements using a spatial photometer ("EZ-contrast" of ELDIM) proved a considerably better viewing angle characteristic of the VAN cell with the compensating layer compared to the non-compensated cell. The same can be seen from Figures 1 to 3, where Figure 1 shows the viewing angle characteristic of an LPP-oriented two-domain VAN-LCD in the off-state, Figure 2 shows the same cell, but with an additional compensating layer according to the invention, and Figure 3 shows for comparison the empty cell without compensating layer between crossed polarisers.

Claims

CLAIMS

1. A compensator comprising a layer of a cholesteric liquid crystal polymer having a helix axis essentially normal to the plane of the layer and a helix pitch sufficiently short that the selective reflection range is of shorter wavelength than visible light.

2. A compensator according to claim 1, wherein the said pitch is less than 300nm.

3. A compensator according to Claim 2, wherein the said pitch is less than 200nm.

4. A compensator according to Claim 3, wherein the said pitch is less than 150nm.

5. A compensator according to Claim 1, wherein the said pitch is less than $350nm/\bar{n}$ where $\bar{n}$ is the mean refractive index of the polymer.

6. A compensator according to any preceding claim, wherein the cholesteric liquid crystal is applied and polymerised in situ.

7. A compensator according to any preceding claim wherein the optical anisotropy Δn of the liquid crystal polymer exceeds 0.25.

8. A compensator according to any preceding claim, wherein the layer has a cholesteric arrangement over at least part of its area.

9. A compensator according to any preceding claim, wherein the polymer layer is photo-oriented.

10. A compensator according to claim 9, wherein the polymer layer adopts the orientation of an underlying linearly photopolymerised layer.

11. A liquid crystal display device comprising a compensator according to any preceding claim.

12. A liquid crystal display device according to claim 11, wherein the compensator extends to the whole viewing area of the device.

13. A liquid crystal display device according to claim 11 or 12 which, in either its white or dark state, has the director of its switching liquid crystal material aligned essentially normal to the compensator.

14. A liquid crystal display device according to any of claims 11 to 13, wherein the liquid crystal cell is vertically aligned nematic.

15. A liquid crystal display device according to any of claims 11 to 13, wherein the liquid crystal cell is hybrid aligned nematic.

16. A liquid crystal display device according to any of claims 11 to 13, wherein the liquid crystal cell is twisted nematic.

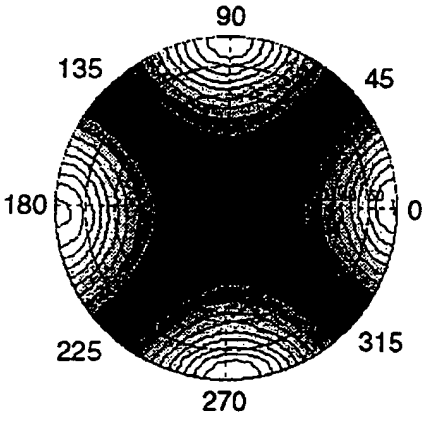


Fig. 1

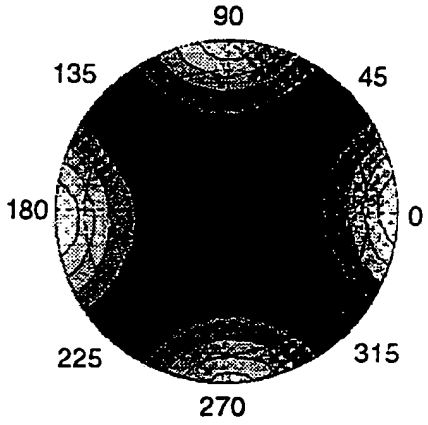


Fig. 2

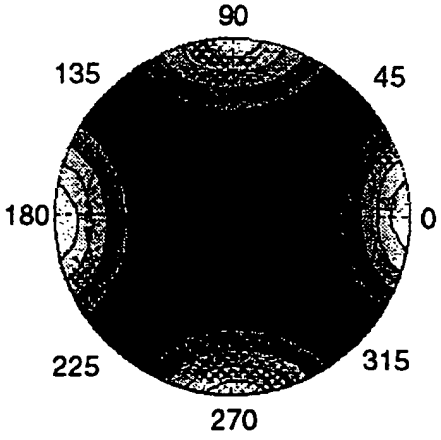


Fig. 3

INTERNATIONAL SEARCH REPORT

Inter ational Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02F1/1335 G02B5/30

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[X] Further documents are listed in the continuation of box C. [X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
2 March 2000	09/03/2000

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